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# **NAVAL POSTGRADUATE SCHOOL**

**MONTEREY, CALIFORNIA**

## **THESIS**

**DETERMINING A RETENTION MODEL FOR THE  
SELECTED MARINE CORPS RESERVE**

by

Andrew D. Dausman

March 2016

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**DETERMINING A RETENTION MODEL FOR THE SELECTED MARINE  
CORPS RESERVE**

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Submitted in partial fulfillment of the  
requirements for the degree of

**MASTER OF SCIENCE IN MANAGEMENT**

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## **ABSTRACT**

This thesis develops a retention model for the Selected Marine Corps Reserve (SMCR). Data for this model were pulled from the Marine Corps' Total Force Data Warehouse for the fiscal years 2009 through 2015. The model forecasts SMCR continuation requirements in lieu of reenlistment requirements because reenlistment contracts in the Marine Corps Reserve are not specific to a particular reserve sub-component.

Using Markov-chain forecasting, the model applies transition rates to the current-year SMCR enlisted inventory to determine the future state of the inventory, by grade and military occupational specialty (MOS). The forecasted inventory is subtracted from the Grade Adjusted Recapitulation (GAR) to arrive at the requisite number of continuations by grade and MOS. The GAR, provided by Headquarters, United States Marine Corps (HQMC), identifies optimal inventory. Manpower planners can use the forecasted continuation requirements to shape retention initiatives and prioritize resources.



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## LIST OF ACRONYMS AND ABBREVIATIONS

AC	Active Component
BMOS	billet military occupational specialty
DOD	Department of Defense
EOS	end of obligated service
FTAP	First Term Alignment Plan
HQMC	Headquarters, United States Marine Corps
IMA	Individual Mobilization Augmentees
IMOS	intended military occupational specialty
MARFORRES	Marine Forces Reserve
MCR	Marine Corps Reserve
MDSD	mandatory drill stop date
MOS	military occupational specialty
NPS	non-prior service
OAP	obligor alignment plan
PEBD	pay entry base date
PMOS	primary military occupational specialty
PS	prior service
PSAP	prior service alignment plan
RC	Reserve Component
RECC	reserve expiration of current contract
RA	Reserve Affairs
RASL	Reserve Active Status List
RRUC	reserve reporting unit code
SelRes	Selected Reserve
SMCR	Selected Marine Corps Reserve
STAP	Subsequent Term Alignment Plan
TFDW	Total Force Data Warehouse



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## **I. INTRODUCTION**

### **A. PURPOSE**

This thesis develops a Markov model to determine the number of enlisted continuations, by military occupational specialty (MOS) and grade, required to meet an optimal force inventory for the Selected Marine Corps Reserve. The model described in this thesis was developed for Reserve Affairs (RA) Division, Manpower & Reserve Affairs, Headquarters, United States Marine Corps. RA does not currently have a model to forecast specific continuation requirements.

### **B. TOTAL FORCE CONCEPT**

The United States Military is comprised of uniformed service members and various categories of civilian members. The Department of Defense (DOD) (2016) defines its Total Force Policy by delineating the following personnel categories:

- Active Component (AC) Military
- Reserve Component (RC) Military
- Civilian Component
- Contracted Services Component
- Host Nation Support Component

This thesis is concerned with the two uniformed military components, with particular focus on the RC. The DOD (2016) further delineates the various categories of RC personnel as follows:

- Ready Reserve
- Standby Reserve
- Retired Reserve

The Ready Reserve, Standby Reserve, and Retired Reserve all include service members that can be mobilized in times of war and national emergency, although the readiness for

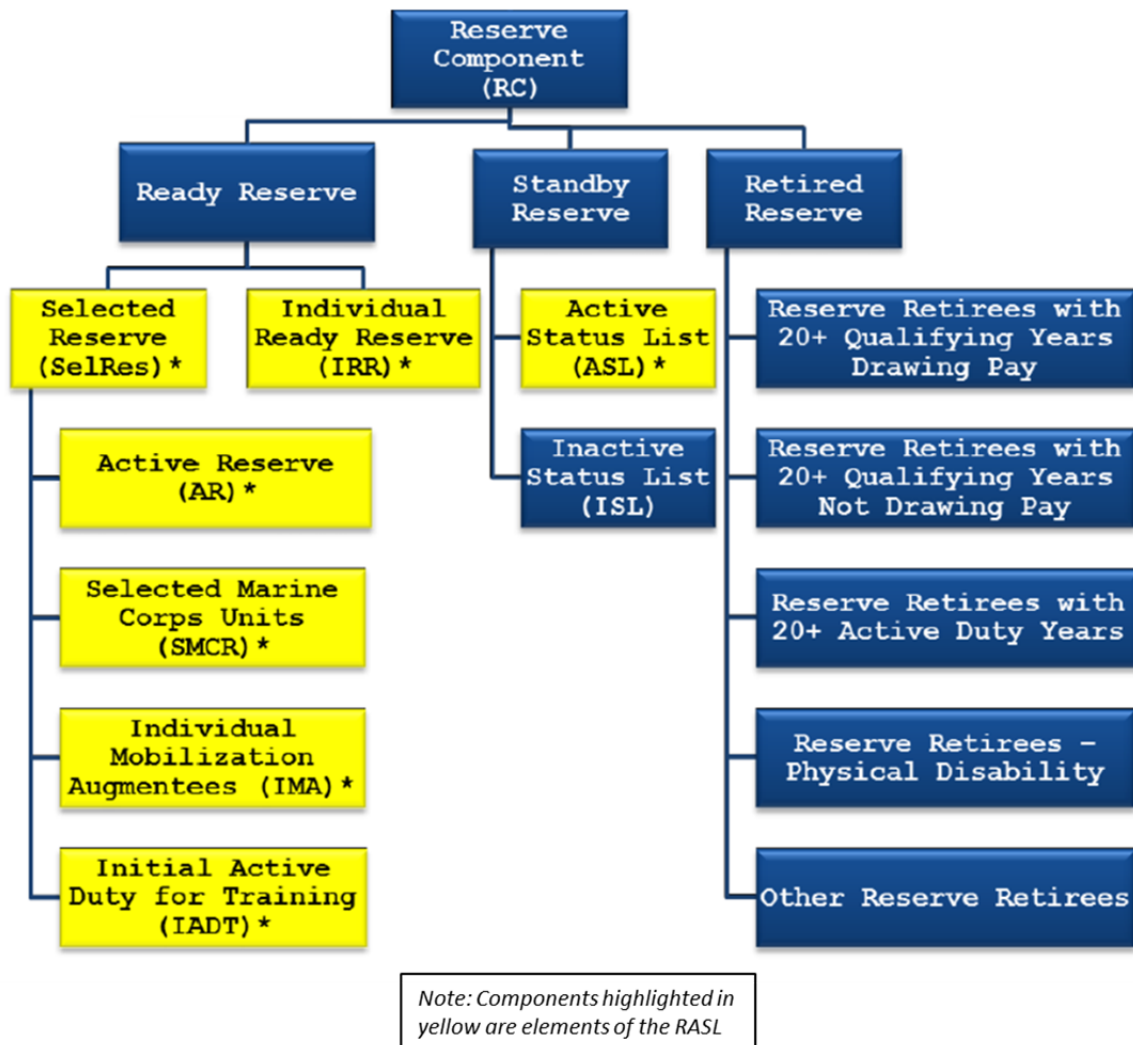
mobilization, as well as the statutory requirements for mobilization, differs for each category.

### **C. MARINE CORPS RESERVE COMPONENT ORGANIZATION**

The Marine Corps is organized along similar lines as the broader DOD with an AC and RC. The Marine Corps' RC organization is described in Figure 1. In accordance with DOD policy, the Marine Corps' RC is comprised of a Ready Reserve, Standby Reserve, and Retired Reserve. Additionally, the Reserve Active Status List (RASL) includes all individual Marines actively serving in the RC, with varying degrees of mobilization potential. Per Headquarters, United States Marine Corps (2015b), the RASL consists of the following elements:

- Active Reserve (AR). Marines in the AR serve on active duty, providing full-time support to the Marine Corps Reserve (MCR).
- Selected Marine Corps Reserve (SMCR) Units. SMCR units are operational Marine Corps units, organized under Marine Forces Reserve. Service in the SMCR is characterized by training during one weekend per month and a two week period once per year.
- Initial Active Duty for Training (IADT). Marines in the IADT category are in the process of completing their initial training.
- Individual Mobilization Augmentees (IMA). IMA Marines are reserve Marines providing part-time support to AC units.
- Selected Reserve (SelRes). The SelRes is an administrative category encompassing the AR program, SMCR units and IMA Marines.
- Individual Ready Reserve (IRR). The IRR is comprised of reserve Marines who can be mobilized to active duty. The IRR includes prior service (PS) Marines completing their period of mandatory service following active duty as well as PS Marines who formerly served in some other RASL sub-component.
- Standby Reserve-Active Status List. Marines in this category are prevented from participating in a paid status while remaining eligible for promotion and unpaid training opportunities. These Marines have limited mobilization potential.

Figure 1. Components of the Marine Corps Reserve



Adapted from Marine Corps Order 1001R.1L, Headquarters, United States Marine Corps (2015b).

#### D. SMCR UNITS

The primary focus of this thesis is the SMCR units that represent the majority of the SelRes for the Marine Corps. Per Headquarters, United States Marine Corps (2015a), the goal end strength of the SMCR is set at 30,729 Marines out of a SelRes end strength of 38,900 Marines. SMCR units are organized under a similar structure as their AC counterparts, and fall under the administrative and operational control of Marine Forces Reserve (MARFORRES). Licari (2013) finds that reserve units are intended to closely replicate AC capabilities and organization. This replication is referred to as “mirror

imaging” (Licari, 2013). Mirror imaging enables SMCR units to adequately reinforce and augment the AC.

SMCR units are comprised of prior service (PS) Marines with previous service in the AC or the SMCR, as well as non-prior service (NPS) Marines. SMCR Marines are generally recruited from within a 100-mile radius of the gaining SMCR unit. The localized nature of the accession pool for SMCR units, relative to the AC, creates unique challenges for personnel management. The Lateral Move Program provides opportunities for SMCR Marines to change their military occupational specialty (MOS) to serve in a qualifying billet. Additionally, selected paygrade/MOS combinations are eligible to receive travel cost reimbursement for Marines commuting more than 150 miles to their SMCR unit.

## **E. REENLISTMENT AND CONTINUATION**

This thesis focuses on enlisted retention in the SMCR. It is instructive to understand the unique retention considerations of the SMCR, relative to the AC. Although both active and reserve retention policies employ similar terms, in the SMCR, there is a significant distinction between contractual reenlistment and continued service in the same sub-component of the MCR.

### **1. AC Reenlistment**

Upon initial accession to the Marine Corps, AC Marines agree to serve for eight years. A typical enlistment contract entails four years on active duty in the AC, followed by four years in the MCR. By default, a Marine leaving active duty after completing an initial period of enlistment will fulfill the MCR portion of the enlistment contract in the IRR, although Marines in this category may elect to serve in other components of the MCR, to include the SMCR, IMA and AR.

AC Marines on their first term of enlistment are considered part of the First Term Alignment Plan (FTAP). FTAP Marines desiring to remain on active duty are offered reenlistment opportunities on a limited basis, depending on the needs of the Marine Corps. Career Marines comprise the Subsequent Term Alignment Plan (STAP). STAP

Marines who meet basic eligibility requirement are offered the opportunity to reenlist at the end of their contracted period of enlistment. Headquarters, United States Marine Corps (HQMC) centrally manages AC reenlistment targets and guidelines in an effort to meet optimal inventory requirements and promotion opportunities for each MOS.

## **2. SMCR Reenlistment and Continuation**

NPS Marines joining the SMCR agree to serve eight years in the RC. A typical NPS contract is six years of service in the SMCR, followed by two years of service in the MCR. In this example, the first six years of an NPS contract is considered mandatory drill participation in the assigned SMCR unit, and the component for the final two years is elective. The IRR is the default component for the final two years of service, although NPS Marines can continue in the SMCR or transfer to another SelRes component. The RC reenlistment process differs significantly from the AC. RC Marines do not reenlist in a specific component of the MCR (e.g., SMCR, IMA, or AR), but rather reenlist in the RC at large. Consequently, a Marine in the SMCR can reenlist for four additional years, and spend the entire period of enlistment in the IRR.

With respect to the AC, the non-specific nature of RC reenlistment contracts necessitates a unique terminology and approach to force retention. The term *continuation* is used throughout this thesis to identify a continuation of service in the SMCR for Marines who are otherwise eligible to transfer to another component of the MCR, or who accept discharge at the end of an existing contract. For NPS Marines, continuation entails continued service in the SMCR past the period of mandatory drill participation. For PS Marines, this thesis defines continuation as continued service in the SMCR in any given year of their existing contract.

Although HQMC uses the reenlistment process to manage personnel inventories for the AC, the contractual limitations of RC reenlistments preclude an analogous management of SMCR inventories. HQMC provides policy guidelines to facilitate a decentralized approach to optimize unit manning levels. Eligible Marines are allowed to serve in any billet that is a match for their MOS and grade. Marines that are not a billet match are transferred to the IRR (Headquarters, United States Marine Corps, 2015).



The retention model in this thesis provides HQMC with specific continuation requirements, by grade and MOS, for the SMCR. The model provides a peer capability to the FTAP/STAP models utilized by AC manpower planners. This new resource is intended to facilitate HQMC's efforts at more accurately targeting its retention plan.

## **F. SCOPE AND METHODOLOGY**

This thesis utilizes a series of Markov models to forecast the future inventory of PS and NPS Marines, and then calculate the required number of continuations by MOS and grade in order to meet an optimal force inventory. The desired inventory is found in the Grade Adjusted Recapitulation (GAR). The forecasted inventory levels of eligible Marines are subtracted from the GAR to arrive at the continuation requirement. The data providing the basis for the Markov models are derived from the Marine Corps' Total Force Data Warehouse (TFDW).

## **G. ORGANIZATION OF STUDY**

Chapter II provides a literature review of the relevant research on Markov model theory and the application of Markov models to Marine Corps manpower management. Chapter III describes the data and methodology used in this thesis. Chapter IV provides the implementation of the Markov models for this thesis. Chapter V contains the research conclusions, and identifies opportunities for further research.

## **II. LITERATURE REVIEW**

### **A. INTRODUCTION**

The existing body of literature related to predictive manpower models in the Marine Corps Reserve (MCR) is limited. Research that is relevant to this thesis can be classified in several broad categories: Markov model theory, retention studies for the Active Component (AC) of the Marine Corps, and studies that are specific to the Reserve Component (RC) of the Marine Corps. This chapter provides an overview of Markov models as they have been applied to manpower research, followed by a discussion of the more specific research concerning manpower studies in the Marine Corps.

### **B. MARKOV MODEL THEORY**

Andrey Markov published his theory in 1907. A Markov chain describes a random process and a Markov model can be used to predict the future state of a system composed of these random processes (Chung, 1967). Although Markov models can be used for a variety of statistical and forecasting applications, the application of Markov models to manpower systems analysis is of particular interest to this thesis.

Bartholomew (1967) provides a brief history of Markov theory as applied to various social phenomena while introducing the specific application of Markov chains for manpower systems with limited inventories. Per Bartholomew (1967):

In [the Markov model] we assume that the total size of the system is fixed rather than the total number of recruits. The recruitment needs are then determined by the losses together with any change which is planned in the system...In manpower applications, where the states are grades, the internal transitions will correspond to promotion, demotion or transfers. (pp. 56–57)

Markov models, then, can be used to estimate the historic behavior of individuals in an organization, and subsequently to forecast the population inventory at some future time.

Moving beyond methodological theory, Sales (1971) applies a Markov chain model to a specific organizational case study for the Civil Service of the United Kingdom. Sales' (1971) research demonstrates that a Markovian transition matrix and its

associated Markov chain is a valid approach to accurately predicting future inventory levels for various paygrades within an organization. Although Sales' approach ignores occupational specialties, she identifies the addition of occupational specialties as a possible opportunity for improvement in a subsequent model.

Bartholomew and Forbes (1979) further refine the application of Markov chains to manpower planning as a means to forecast the future employment states of a given population. Their research provides a comprehensive treatment of the transition matrices at the heart of the Markov model. Of note, they identify some primary considerations in building transition models:

- (a) What will the grade (or age, or length-of-service) structure be at various dates in the future if present patterns of loss and promotion continue?
- (b) What should the promotion rates and recruitment number be in order to achieve a desired structure in a specified time? (p. 85)

Bartholomew and Forbes also detail the role of attrition, or wastage, in building a Markov model. Wastage occurs when individuals leave a system. This component of a Markov model is important because it reflects the role of employee choice in leaving an organization; these choices are beyond the control of the employer. Additionally, wastage provides job openings and it is, consequently, the cause for promotion opportunities and new accessions.

## **C. PREVIOUS STUDIES: MARINE CORPS ACTIVE COMPONENT**

North and Quester (1992) analyze the Marine Corps' model for forecasting enlisted inventory and calculating the requisite number of reenlistments by grade and MOS. Their research identifies several shortcomings of the existing model, and designs an updated model that better matches real-world conditions. Of note, they find that the existing model puts all Marines in the same category for reenlistment, regardless of the Marines' years of service and contract length. Additionally, the time window used by the existing model to calculate inventories was too short to adequately forecast the inventories in future years.

Following up on their analysis, North and Quester (1992) develop a new model to address the problematic components of the existing model. In their model, North and Quester calculate continuation rates for first-term Marines separately from subsequent-term Marines. Additionally, their steady-state Markov chain model generates the requisite number of reenlistments to match long-term inventory requirements. These findings better model historic records, and consequently, should provide more accurate future projections than the previous model.

Nguyen (1997) provides an analysis of the Marine Corps' enlisted retention model after the service adopted the recommendations provided by North and Quester's research (as described above). Nguyen finds that using a weighted-average of historical continuation rates (in calculating the model's continuation rates) may overestimate or underestimate the actual continuation rate depending on cyclic trends in annual continuation rates. He also identifies systemic rounding errors that have a deleterious effect on the inventory forecasts. Nguyen's findings are significant to the greater body of research by identifying the importance of accurately determining the model's continuation rates. The method (e.g., simple historical average, weighted average, smoothing) used to determine the rates needs to be tested against historical inventory levels.

Conatser's (2006) research focuses on forecasting the number of reenlistments for Marines in the First Term Alignment Plan (FTAP) and Subsequent Term Alignment Plan (STAP). Using classification trees, Conatser identifies the best variables to use in logistic regression models to forecast future reenlistment levels by MOS and grade. Conatser finds that different MOSs exhibit varying reenlistment behavior and, consequently, require varying logistic regression models accurately forecast MOS-specific reenlistment rates.

Raymond (2006) provides a Markov model-based approach to forecast the requisite number of reenlistments in a given year, relative to the Grade Adjusted Recapitulation (GAR). The GAR represents the ideal inventory by MOS and grade, given fiscal constraints and restrictions of law and policy. Relative to the Marine Corps' official model at that time, Raymond's approach offers a less complex approach to forecasting.

When Raymond was conducting his research, the Marine Corps utilized two separate forecasting models, one for the FTAP population and another for the STAP population. Raymond finds that a single model (combining FTAP and STAP) can adequately forecast the required number of reenlistments.

Raymond's (2006) model is based on the inventory of Marines who will not be eligible for reenlistment in the next fiscal year. He calculates the continuation rates for this population, by grade and MOS, and then subtracts the forecasted inventory from the GAR. The resultant inventory from this subtraction represents the desired number of reenlistments to meet the GAR in the upcoming fiscal year. Raymond's approach is unique in that it calculates the reenlistment requirements for the entire enlisted population without regard to FTAP or STAP classifications.

#### **D. PREVIOUS STUDIES: MARINE CORPS RESERVE COMPONENT**

Emery (2010) develops an update to an existing model that forecasts the end strength of the SELRES. He finds that using exponential smoothing to model annual inventory losses is more accurate than a weighted moving average. Additionally, Emery identifies a different smoothing factor for each sub-category of personnel within the SELRES. Concerning the SMCR, Emery finds that a relatively high smoothing factor, heavily weighing the most recent time periods, provides the most accurate forecasts. Consequently, SMCR inventory trends (at least in aggregate end strength) are dominated by the inventory behavior in the previous year.

Erhardt (2012) provides Markov models to forecast enlisted end-strength in the SMCR for both PS and NPS Marines. His models use aggregate transition rates from each month within a fiscal year, and he finds that these rates lead to model results outside of the Markovian stationarity assumption. Erhardt recommends that future end-strength models incorporate individual transition matrices for each month within a fiscal year. This recommendation is realistic for end-strength forecasts, but it is likely to be infeasible for forecasts of much smaller inventories (e.g., stocks of SMCR Marines categorized by grade and MOS).

Licari (2013) provides another example of a Markov model for manpower planning in the SMCR. Specifically, his research develops a model for SMCR officer end-strength and accession forecasts. Licari finds that aggregate monthly transition rates performed as well as unique monthly rates for PS officers. Given the small population size and highly variable monthly transition rates, Licari's model for NPS officers provided unreliable results. These results are instructive in emphasizing the need to tailor transition rate methodology to new Markov models.

## **E. CHAPTER SUMMARY**

The overview of the relevant research in this chapter is grounded in the historical development of Markov models for social processes in general and for manpower applications in particular. The military-specific research in this field is limited, but sufficient to outline some general principles for Markov-based military retention models. The published research discussed earlier is helpful in identifying replicable methodologies that can be applied to new Markov models for SMCR manpower forecasting.

Although a retention model specific to the SMCR's enlisted population has not yet been developed, the existing models developed for the Active Component provide a means to scope the unique problem of SMCR force modelling and retention. Raymond's (2006) research, in particular, lends itself to adaptation for an SMCR enlisted retention model. With respect to transition rates (unique monthly rates, aggregate monthly rates, or annual rates), the SMCR-specific research indicates that there are not any clear guidelines. Rather, experimentation is required for each unique Markov model in order to develop the most appropriate time frame for transition calculations.

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### III. DATA AND METHODOLOGY

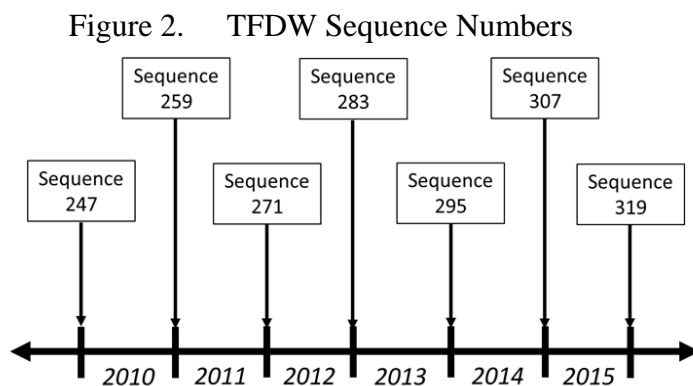
#### A. INTRODUCTION

This chapter describes the data and methodology employed in this thesis. The sections in this chapter provide an overview of the data source, key variables and conceptual framework for the thesis. Additionally, this chapter explains the theoretical approach behind the model developed for this research.

#### B. DATA SOURCE

The data for this thesis were provided by HQMC RA and pulled from the Marine Corps Total Force Data Warehouse (TFDW). According to Headquarters, United States Marine Corps (2016), the TFDW contains over four decades' worth of manpower records, compiled from more than 20 sources. The TFDW has a web-based interface that facilitates custom queries and reports.

The data in the TFDW is organized by sequence and each sequence represents a monthly snapshot of Marine Corps manpower data. This thesis uses sequences from the final day of the fiscal year (September 30) for each fiscal year (FY) from 2009 through 2015. The seven years of data were provided as seven individual data sets. The selected sequences only include the records of SMCR Marines. Figure 2 provides a graphical representation of the TFDW sequences found in this thesis.



Adapted from Raymond, J.D. (2006). *Determining the number of reenlistments necessary to satisfy future force requirements* (Master's thesis). Retrieved <http://hdl.handle.net/10945/2622>



## **C. RESEARCH SOFTWARE**

This thesis employs Stata (Release 13) and Microsoft Excel (2010). Stata is used to manage the data and handle the significant amount of arithmetic calculations required for the model. Excel is used to calculate the model's Markov chains and tabulate the results. These programs were chosen because both are currently in use at HQMC Reserve Affairs, and the model is intended to provide a turnkey solution to that agency. The model can be modified, or updated with new data, using existing software at HQMC.

## **D. LONGITUDINAL DATABASE**

In order to build the model for this thesis, the individual data sets are combined to form a single longitudinal database. The records for unique individuals can exist in multiple years, so the combined database has a unique record for each Marine in a given sequence. The database has 225,019 individual records, and tracks the career progression of individual enlisted Marines in the SMCR. Stata is used to merge the individual data segments and transform the data into the format required for the model. Although some variables were provided from the TFDW data pulls, several variables in use by the model required additional Stata coding.

## **E. VARIABLES**

### **1. Dataset Variables**

The variables in this section are present in the dataset prior to any transformations in Stata. With the exception of the ID variable, each of these variables are present in the TFDW.

#### ***a. ID***

The ID variable is a unique identifier for each individual Marine record. This variable is a system-generated variable, and is used in lieu of the Social Security number or Department of Defense identification number.

***b. Presgrade***

Presgrade is a Marine's grade/rank in a given sequence.

***c. Primary MOS***

The primary military occupational specialty (PMOS) is a Marine's principle specialty and career field.

***d. Intended MOS***

The IMOS is the MOS assigned to new recruits. It reflects a Marine's intended PMOS prior to formally receiving the PMOS. The IMOS variable is used to back fill missing PMOS fields.

***e. Billet MOS***

The billet MOS (BMOS) reflects the MOS for which an individual billet is coded. The BMOS is used to backfill missing PMOS fields if the IMOS was also missing.

***f. Sequence***

The sequence code reflects the particular TFDW sequence for a given record. This is important in providing the basis for state-change calculations between sequences. Each sequence corresponds to the final day of a given fiscal year.

***g. Component Code***

The component code reflects a Marine's active duty status. Although the model only contains the records for SMCR Marines, some SMCR Marines serve in a mobilized status on active duty.

***h. Reserve Component Code***

The reserve component code characterizes a reserve Marine's sub-component within the MCR. The TFDW data sequences include SMCR reserve component codes.

***i. Reserve Record Status***

This variable identifies an individual's record status. This field was used to screen ineligible records (e.g., deserter status).

***j. Reserve Expiration of Current Contract***

The reserve expiration of current contract (RECC) code reflects the end date of a reserve enlistment contract. The enlistment contract normally exceeds the SMCR drilling requirement.

***k. End of Obligated Service***

The end of obligated service (EOS) date reflects the end of the initial contractual period of service.

***l. Reserve Reporting Unit Code***

The reserve reporting unit code (RRUC) identifies a reserve Marine's present unit assignment. This variable was not used in the model, but retained in the dataset for prospective future use.

***m. Pay Entry Base Date***

The pay entry base date (PEBD) is the beginning date of contractual service.

***n. Mandatory Drill Stop Date***

The MDSD characterizes the last day of a contractual drilling requirement. This variable is important in subdividing the model's inventory. Obligors are the principal focus of the model's inventory forecasts and, specifically, obligors who have not yet entered the final year of their drilling requirement.

When the MDSD was missing, the PEBD was used to calculate effective MDSDs. Although most initial SMCR contracts require six years of SMCR service and two years of IRR service (i.e., 6x2), there are also 5x3, 4x4, and 3x5 contracts. Stata is used to calculate effective MDSDs based on the contract type and the PEBD. For example, for a 6x2 contract, the MDSD is calculated as:  $PEBD + 6 \text{ years}$ .

***o. Anniversary Date***

The anniversary date reflects a member's entry into active status within the MCR. This date is not used in the thesis model, but is retained for future use.

**2. Coded Variables**

The variables in this section were created, or derived, from existing variables. The variable transformations are executed in Stata.

***a. MOSGRADE***

MOSGRADE is the concatenation of a Marine's present grade and PMOS in a given sequence.

***b. Obligor***

Obligor is an indicator variable for Marines who are serving within a contractual drilling obligation, but are not yet in their final year of obligation.

***c. Prior Service Alignment Plan***

Prior Service Alignment Plan (PSAP) is an indicator variable for prior service Marines. The PSAP population includes both prior AC and prior RC Marines who no longer have a drilling obligation.

***d. Obligor Alignment Plan***

Obligor Alignment Plan (OAP) is an indicator variable for Marines serving a period of contractual drilling obligation and their MDSD falls within the current year. In this model, the OAP variable includes prior service Marines with a drilling obligation and an MDSD in the current FY. The inclusion of prior service Marines is a departure from the established definition of the OAP population. Per current planning policy, the OAP population only includes Marines serving their initial enlistment contract and assigned an MDSD in the current FY. This model includes PS Marines in the OAP population for purposes of expediency.

***e. Gain\_obligor***

This indicator variable provides a reference for an accession in a given sequence (fiscal year) for the obligor inventory.

***f. Gain\_OAP***

This indicator variable provides a reference for an accession in a given sequence (fiscal year) for the OAP inventory.

***g. Gain\_PSAP***

This indicator variable provides a reference for an accession in a given sequence (fiscal year) for the PSAP inventory.

***h. Cont\_obligor***

This indicator variable defines an obligor record that continues into the next sequence with the same grade.

***i. Cont\_OAP***

This indicator variable defines an OAP record that continues into the next sequence with the same grade.

***j. Cont\_PSAP***

This indicator variable defines a PSAP record that continues into the next sequence with the same grade.

***k. Promote\_obligor***

This indicator variable provides a reference for an obligor record that is promoted by a single grade in the next sequence.

***l. Promote\_OAP***

This indicator variable provides a reference for an OAP record that is promoted by a single grade in the next sequence.

***m. Promote\_PSAP***

This indicator variable provides a reference for a PSAP record that is promoted by a single grade in the next sequence.

***n. Promote2\_obligor***

This indicator variable provides a reference for an obligor record that is promoted by exactly two grades in the next sequence.

***o. Promote2\_OAP***

This indicator variable provides a reference for an OAP record that is promoted by exactly two grades in the next sequence.

***p. Promote2\_PSAP***

This indicator variable provides a reference for a PSAP record that is promoted by exactly two grades in the next sequence.

***q. Reduce\_obligor***

This indicator variable provides a reference for an obligor record that is reduced, or demoted, by one grade in the next sequence.

***r. Reduce\_OAP***

This indicator variable provides a reference for an OAP record that is reduced, or demoted, by one grade in the next sequence.

***s. Reduce\_PSAP***

This indicator variable provides a reference for a PSAP record that is reduced, or demoted, by one grade in the next sequence.

## F. CONCEPTUAL MODEL

### 1. Theoretical Approach

The model in this thesis is effectively a collection of individual models; there is one Markov model for each PMOS found in the SMCR GAR. Each MOS model utilizes a Markov chain to forecast the future inventory of obligor Marines in the next fiscal year. For the purposes of this thesis, the obligor inventory includes all SMCR enlisted Marines with a contractual drilling requirement and whose obligation does not expire in the current fiscal year. This population reflects the inventory that will be present throughout the entirety of the next fiscal year. All Markov chain forecasts in this thesis are for the obligor population.

The MOS models follow an established methodology for Markov models with a fixed recruiting vector. Per Bartholomew and Forbes (1979), the equation for fixed recruitment models is as follows:

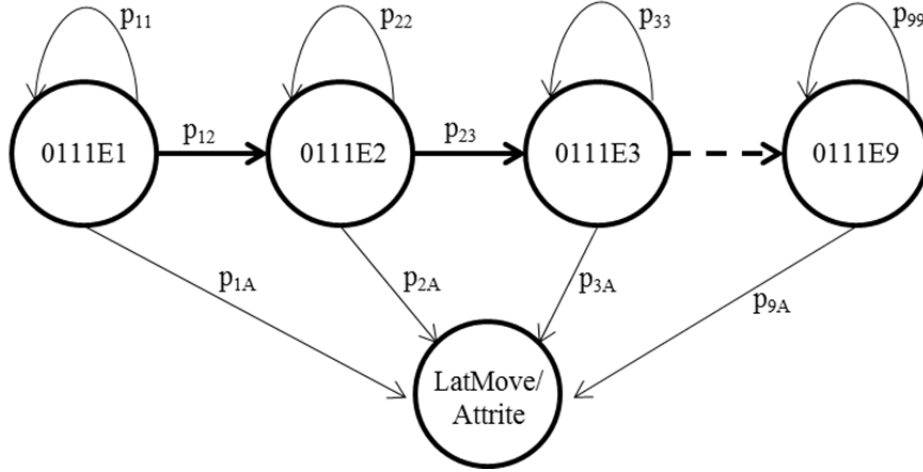
$$\mathbf{n}(t) = \mathbf{n}(t-1)\mathbf{P} + R(t)\mathbf{r}$$

For this equation:

- $\mathbf{n}(t)$  is the forecasted inventory at time  $t$
- $\mathbf{n}(t-1)$  is the inventory at the previous time
- $\mathbf{P}$  is the transition matrix containing the transition probabilities
- $R(t)$  is the total number of accessions at time  $t$
- $\mathbf{r}$  is the recruiting vector that describes the distribution of accessions across the model's states. (Sobondo, 2014)

A graphical representation of the Markov model for a single MOS (0111) is provided in Figure 3. For this thesis, all Markov state calculations are based on the concatenated variable MOSGRADE. In this example, the probability  $p_{11}$  is the probability that an obligor Marine with the MOS of 0111 in the grade of E1 will remain in the same grade in the next time step. The probability  $p_{12}$  is the probability that Marine will transition from 0111E1 to 0111E2. The probability  $p_{1A}$  is the probability that a Marine in state 0111E1 will attrite from the MOS. Attrition could be the result of either transfer from the SMCR, or a transfer to another MOS.

Figure 3. Markov Model Example for MOS 0111



## 2. Transition Rates

The example in Figure 3 captures the most common transition state changes for a single MOS. However, the models in this thesis also calculate transition rates for individuals that are promoted two grades in a single transition, as well as any reductions in grade. Although the arithmetic operations employed in determining these transition rates are straightforward, the volume of calculations required for 164 MOSs is significant. Stata is used to calculate the transition rates, by MOSGRADE, for the Marines in the obligor population. The model calculates an aggregate transition rate across all fiscal years in the dataset and also calculates a weighted average transition rate for the three most recent fiscal years.

## 3. Transition Matrix

The calculated transition rates are the basis for the model's transition matrices. There is a transition matrix for each MOS with the possible states and associated probabilities. Figure 4 is an example of a transition matrix for the 0111 MOS, with the transition rates for the recorded state changes in the obligor inventory.



Figure 4. Sample Transition Matrix for MOS 0111

**“TO” State:**

“FROM” State:	MOSGRADE	111E1	111E2	111E3	111E4	111E5	111E6	111E7	111E8	111E9
	111E1	0.01	0.13	0.76	0.00	0.00	0.00	0.00	0.00	0.00
	111E2	0.00	0.04	0.84	0.01	0.00	0.00	0.00	0.00	0.00
	111E3	0.00	0.00	0.67	0.11	0.00	0.00	0.00	0.00	0.00
	111E4	0.00	0.00	0.00	0.25	0.04	0.00	0.00	0.00	0.00
	111E5	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
	111E6	0.00	0.00	0.00	0.00	0.00	0.08	0.01	0.00	0.00
	111E7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	111E8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	111E9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

#### 4. Calculating Inventory and Accessions

The on-hand inventory, by MOSGRADE, for the current fiscal year is determined by the model using the indicator variable for the obligor population. Accessions into each MOS are calculated based on a record’s appearance in a given sequence using one of the accession indicator variables. The model produces the accessions, by MOSGRADE, for each of the three sub-populations: obligor, OAP and PSAP.

#### 5. Forecasting the Inventory

Using the fixed recruitment equation, the Markov chain models can produce the forecasted obligor inventory after the current inventory, accessions and transition rates have been determined. Stata is used to calculate inventory, accessions and transition rates. These determinant values are exported to Excel for the Markov chain calculations.

### G. USING THE GAR TO CALCULATE REQUIRED CONTINUATIONS

#### 1. GAR Overview

HQMC RA produces a combined GAR for the SMCR and the IMA. For this thesis, HQMC RA developed an SMCR-only GAR. This GAR identifies the required SMCR inventory requirement by grade and MOS. For this thesis model, the GAR represents the goal inventory by which the desired continuations are calculated. Figure 5 is a sample from the SMCR GAR used in this thesis.

Figure 5. SMCR GAR for Selected MOSs

MOS	E9	E8	E7	E6	E5	E4	E3/E2/E1	Total
0111	2	7	23	49	88	137	338	644
0211	0	3	32	53	145	0	0	233
0231	0	3	11	23	43	68	148	296
0241	0	0	10	16	35	0	0	61

## 2. GAR Transformation

To utilize the GAR in the Markov chain models, the GAR is read into STATA and transformed into a format better suited to the model's inventory calculations. Figure 6 is a sample of the transformed GAR for the MOS 0111. The transformed GAR uses the model's existing variables, reshapes the data, and adds the concatenated variable MOSGRADE.

Figure 6. Transformed GAR for MOS 0111

PMOS	Presgrade	GAR	MOSGRADE
111	1	0	111e1
111	2	0	111e2
111	3	338	111e3
111	4	137	111e4
111	5	88	111e5
111	6	49	111e6
111	7	23	111e7
111	8	7	111e8
111	9	2	111e9

## 3. Continuation Requirements

The continuation requirements can be calculated once the model has produced: the forecasted obligor inventory, transition rates, accessions, on-hand inventory, and GAR requirements. The continuation calculation can be explained by this equation:

$$C_{OAP-PSAP} = GAR - (I_{OBL} + R_{PS} + R_{NPS})$$

For this equation:

- $C_{OAP-PSAP}$  are the continuation requirements for the combined OAP and PSAP populations

- GAR is the SMCR grade adjusted recapitulation
- $I_{OBL}$  is the forecasted obligor inventory
- $R_{PS}$  is prior service accessions
- $R_{NPS}$  is non-prior service accessions

## **H. SUMMARY**

This chapter provides an overview of the data employed in this thesis and the methodology behind the thesis model. This thesis employs fixed recruitment Markov chain models to forecast the SMCR obligor inventory. The model uses the forecasted inventory and the GAR to arrive at the required number of SMCR continuations by MOS and grade.

## IV. MODEL RESULTS

### A. RESULTS OVERVIEW

Each time the model is run, Stata updates an MOS-specific workbook in Microsoft Excel. Each workbook contains a separate worksheet for the on-hand inventory, transition state-change inventories, accession inventory, and the MOS-specific GAR requirement. The main worksheet contains the transition matrix, Markov-chain calculations, GAR calculations, and continuation requirements for each grade. These workbooks are created in Excel as blank templates prior to running the model in Stata. Once the model is run in Stata, the exported data auto-populates the appropriate Excel workbook. Figure 7 is the model output for MOS 0111.

Figure 7. Model Output for MOS 0111

MOSGRADE	Transition Matrix:								
	111E1	111E2	111E3	111E4	111E5	111E6	111E7	111E8	111E9
111E1	0.01	0.13	0.76	0.00	0.00	0.00	0.00	0.00	0.00
111E2	0.00	0.04	0.84	0.01	0.00	0.00	0.00	0.00	0.00
111E3	0.00	0.00	0.67	0.11	0.00	0.00	0.00	0.00	0.00
111E4	0.00	0.00	0.00	0.25	0.04	0.00	0.00	0.00	0.00
111E5	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
111E6	0.00	0.00	0.00	0.00	0.00	0.08	0.01	0.00	0.00
111E7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
111E8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
111E9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R	r	r	r	r	r	r	r	r	r
175	0.165714286	0.41142857	0.10285714	0.205714286	0.045714286	0.051428571	0.0057143	0.005714286	0.005714286
Gains	29	72	18	36	8	9	1	1	1
n(0)	29	84	445	49	3	1	0	0	0
n(1)	29	80	410	97	10	9	1	1	1
n(1) ADJ			519	97	10	9	1	1	1
GAR	0	0	338	137	88	49	23	7	2
Req Cont	0	0	0	40	78	40	22	6	1

### B. TRANSITION MATRICES

The indicator variables for continuation, promotion and grade reduction, are modeled in Stata to calculate the transition rates for each MOS and grade. The results for each MOS are exported to an MOS-specific workbook in Excel. It is possible that the model's transition matrices do not capture every possible intra-MOS transition probability. For example, a Marine promoted more than twice in a single FY would not

be captured by this model. Similarly, reductions in more than a single grade per FY are not included in this model. The rate of actual occurrence in either instance is trivial to the degree that inclusion in the model is unnecessary.

The model calculates both weighted and un-weighted transition rates. The unweighted rates are an average of all continuation/promotion/reduction rates across all of the fiscal years in the dataset. The weighted rates provide a weighted average of the three most-recent fiscal years in the dataset. The most recent year's data is given a weight of three, the next most recent year's data is weighted by two, and the latest year is not given a weight. This weighting scheme is a commonly used forecasting convention at HQMC RA; the model is designed so that an alternative forecasting technique could be used in a future iteration of the model. Figure 8 is an example of the model output for the continuation-in-grade rates for the 0111 MOS.

Figure 8. Continuation-in-Grade Rates for the 0111 MOS

MOSGRADE	WEIGHTED	UNWEIGHTED
111E1	0.003	0.011
111E2	0.024	0.043
111E3	0.685	0.673
111E4	0.258	0.251
111E5	0.050	0.034
111E6	0.104	0.077

### C. ON-HAND INVENTORY

The model calculates the on-hand SMCR enlisted inventory in three sub-populations: obligor, OAP and PSAP. The inventories are calculated in Stata and then exported to Microsoft Excel. The outputs are delineated by the concatenated variable: MOSGRADE. Figure 9 provides an example of the model output for the 0111 MOS obligor population.

Figure 9. On-Hand Obligor Inventory for MOS 0111 (FY 2015)

MOSGRADE	ONHAND
111e1	29
111e2	84
111e3	445
111e4	49
111e5	3
111e6	1

#### D. ACCESSIONS

Stata calculates the accessions by identifying the records making their first appearance in a given sequence (FY). The resultant inventory is further divided by FY, MOSGRADE, and alignment plan: obligor, OAP, and PSAP. Figure 10 is the model output for FY15 for the 0111 MOS. Within each MOS workbook, the accessions are tabulated under the “Gains” tab.

Figure 10. FY15 Accessions by Alignment Plan for the 0111 MOS

GAIN_OBLIGOR	GAIN_OAP	GAIN_PSAP	MOSGRADE
29	0	0	111e1
72	0	0	111e2
13	0	5	111e3
0	7	29	111e4
0	0	8	111e5
0	0	9	111e6
0	0	1	111e7
0	0	1	111e8
0	0	1	111e9

#### E. INVENTORY FORECAST

The on-hand inventory, transition rates, and accessions are automatically exported to MOS-specific workbooks in Excel. Once the data is present in Excel, the Markov-chain inventory forecast is ready to run as soon as a workbook is opened. Figure 7 provides an example of the inventory forecast for the 0111 MOS. The elements of the forecast are as follows:

- $(n)0$  is the on-hand inventory for the current FY

- $(n)I$  is the forecasted inventory in the next FY
- $(n)IADJ$  is the forecasted inventory with a rollup of grades E1 through E3. The GAR requirements capture E1, E2, and E3 grades in a single category.
- $R$  is the scalar value for all accessions
- $r$  is the accession distribution vector

## **F. GAR CALCULATIONS**

Using the transformed GAR (see Figure 6), the model exports the MOS-specific portion of the GAR to each MOS workbook. The GAR requirements are mapped to the main tab (see Figure 7) via cell addressing in Microsoft Excel. The arithmetic operations to subtract the forecasted inventory from the GAR are embedded in each MOS-specific workbook template. *Req cont* (see Figure 7) reflects the estimated number of required continuations for each grade in that MOS.

## **G. MOS-SPECIFIC CONSIDERATIONS**

The figures illustrating the previous sections all use the 0111 MOS as an example. The 0111 MOS includes all enlisted grades: E1 through E9. The model performs similarly for other MOSs that are structured with the grades E1–E9. Alternative MOS structures include: E1–E5, E5–E9, and E8–E9. Regardless of the MOS grade structure, the model calculates the continuation requirements using the same order of operations. However, the results are structured differently depending on an MOS’s constituent population.

### **1. Feeder MOSs**

Some MOSs are entry-level specialties that feed advanced MOSs. For example, the MOS 0369, Infantry Unit Leader, is fed by the following MOSs: 0311, 0331, 0341, 0351, and 0352 (Headquarters, United States Marine Corps, 2013). This model calculates the required continuations for each MOS separately. Figure 11 is the model output for the feeder MOS, 0311, and Figure 12 is the model output for the gaining MOS, 0369.

Figure 11. Model Output for MOS 0311

MOSGRADE	Transition Matrix:								
	311E1	311E2	311E3	311E4	311E5	311E6	311E7	0	0
311E1	0.03	0.15	0.71	0.00	0.00	0.00	0.00	0.00	0.00
311E2	0.00	0.04	0.85	0.00	0.00	0.00	0.00	0.00	0.00
311E3	0.00	0.00	0.66	0.18	0.00	0.00	0.00	0.00	0.00
311E4	0.00	0.00	0.00	0.31	0.08	0.00	0.00	0.00	0.00
311E5	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
311E6	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
311E7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R	r	r	r	r	r	r	r	r	r
723	0.229598893	0.45781466	0.12863071	0.105117566	0.078838174	0	0	0	0
Gains	166	331	93	76	57	0	0	0	0
n(0)	170	374	2069	298	24	0	0	0	0
n(1)	171	370	1895	543	82	0	0	0	0
n(1) ADJ			2436	543	82	0	0	0	0
GAR	0	0	2141	784	390	0	0	0	0
Req Cont	0	0	0	241	308	0	0	0	0

Figure 12. Model Output for MOS 0369

MOSGRADE	Transition Matrix:								
	369E6	369E7	369E8	369E9	0	0	0	0	0
369E6	0.0864	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
369E7	0.0000	0.0036	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
369E8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
369E9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R	r	r	r	r	r	r	r	r	r
26.0000	0.653846154	0.30769231	0.03846154	0	0	0	0	0	0
Gains	17	8	1	0	0	0	0	0	0
n(0)	19	0	0	0	0	0	0	0	0
n(1)	19	8	1	0	0	0	0	0	0
GAR	206	60	68	14	0	0	0	0	0
Req Cont	187	52	67	14	0	0	0	0	0

For the 0311/0369 example, some portion of the 0311E5 population is transferring to the 0369E6 population. The model does not identify this component of attrition from the 0311 MOS. Rather, the model calculates each MOS' requirements as a discrete population, without regard to the interrelationship between feeding and gaining MOSs.



## 2. MOS 8999: First Sergeant/Sergeant Major

MOS 8999 is the primary MOS for First Sergeants and Sergeants Major. Figure 13 is the model output for this MOS. For this MOS, the on-hand obligor inventory is zero because none of the Marines have a drilling obligation. The entire inventory of MOS 8999 Marines exists in the PSAP population. For populations without a significant obligor inventory, the model provides much less insight than in the case of populations with significant obligor inventories. There are an insufficient number of observations to generate meaningful obligor inventory forecasts for MOSs that are predominately comprised of PSAP Marines.

Figure 13. Model Output for MOS 8999

MOSGRADE	Transition Matrix:								
	8999E8	8999E9	0	0	0	0	0	0	0
8999E8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8999E9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R	r	r	r	r	r	r	r	r	r
12.0000	1	0	0	0	0	0	0	0	0
Gains	12	0	0	0	0	0	0	0	0
n(0)	0	0	0	0	0	0	0	0	0
n(1)	12	0	0	0	0	0	0	0	0
GAR	138	60	0	0	0	0	0	0	0
Req Cont	126	60	0	0	0	0	0	0	0

## H. SUMMARY

The model forecasts the future obligor inventory, in addition to accessions, for each GAR MOS. The resultant inventory is subtracted from the GAR to arrive at the required number of continuations. Note that continuations reflect the number of Marines that need to continue serving in the SMCR irrespective of their reserve enlistment contracts. Because a reserve contract cannot compel SMCR service, the model does not identify enlistment contract requirements. Consequently, the required number of continuations in a given MOS will be greater than the number of Marines in that MOS approaching the end of their enlistment contracts.

## **V. CONCLUSIONS AND RECOMMENDATIONS**

### **A. CONCLUSION**

This thesis develops a retention model for the SMCR. The model identifies continuation requirements, because there is a distinction between contractual reenlistment and SMCR service. Although existing policy initiatives incentivize continued service in the SMCR, specific continuation goals may enable manpower planners to better target the appropriate grades and MOSs.

The model is designed to generate its results by grade and MOS by using the GAR as the baseline requirement for optimal force inventory. The model identifies the continuation requirements by forecasting the future inventory of obligor Marines and accounting for annual accessions in all inventory categories. The resultant forecasted inventory is subtracted from the GAR to arrive at the model's continuation requirements.

The model is designed for annual use. The model can be refreshed on an annual basis by updating the latest data sequence from TFDW. Once updated, the model will automatically generate new continuation requirements for each GAR MOS. The model in this thesis generates both unweighted and weighted transition rates; however, the transition rate calculation method can also be updated as needed.

### **B. RECOMMENDATIONS AND FURTHER RESEARCH**

We recommend that manpower planners consider using specific continuation targets in allocating resources for force retention. The implementation of centralized planning for career force retention goals will align the SMCR with Active Component retention methods. This thesis provides a model for the entire enlisted SMCR inventory; however, it may be appropriate to develop separate models to address the OAP and PSAP populations as distinct populations.

The following topics are recommended for future research.

- Identify the optimal weighting of previous years' data in developing transition rates for inventory forecasts.

- A retention model that generates contractual reenlistment requirements for the OAP and PSAP populations. Once identified, the statistical relationship between reenlistment and continuation may be helpful in further refining the force retention model used in this thesis.
- Analysis of Career Planner actions on both retention and continuation. Data from the Total Force Retention System could be used to identify the relationship between end-of-contract interviews, contractual reenlistments and SMCR service continuation.

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